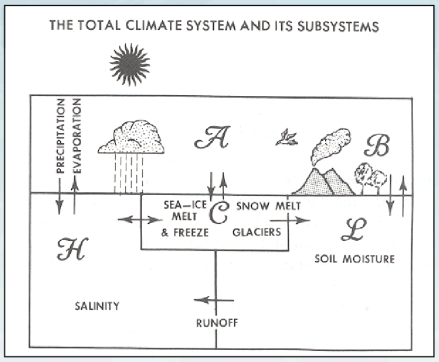
Great Lakes Ice and Climate Research



Jia Wang

Ice Climatology & Modeling Team

Team Members:
Anne Clites (GLERL), Xuezhi Bai (CILER), Haoguo Hu (CILER), Ray Assel, (CILER), Yi Yang (CILER)
Ayumi Fujisaki, (CILER), Lin Luo (CILER)

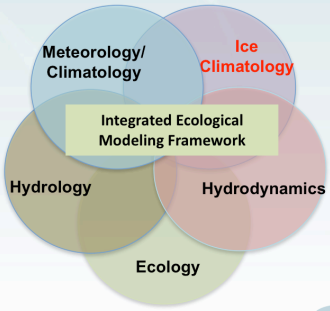
Ice Climatology and Modeling Team

1) Lake ice / regional climate variability

2) Develop a capability for hindcasting, downscaling and projecting climate scenarios

3) Conducts interdisciplinary research and tests hypotheses using models

Integrated Modeling Framework

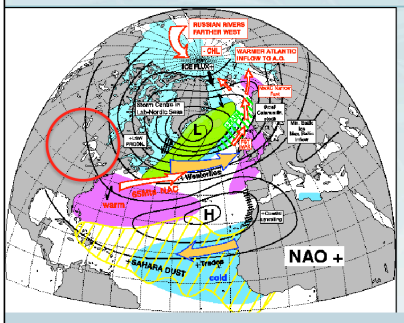


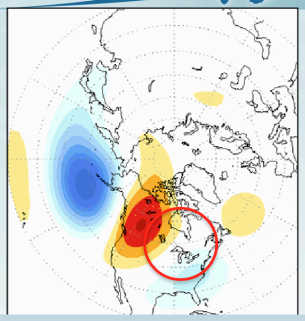
1) Investigates relationships between lake ice / regional climate variability and changing climate patterns.
2) Develops and implements coupled ice-circulation-ecosystem models to simulate ice-circulation-ecosystem's response to a changing climate, and to develop a capability for downscaling and projecting climate.
   scenarios into Great Lakes regional scales.
3) Conducts interdisciplinary research and tests hypotheses using models along with *in situ* and satellite measurements.

Key Scientific Questions

1) Which large-scale climate patterns (forcings) drive seasonal to decadal variability of lake ice and regional climate?
2) What factors determine lake ice predictability on time scales from season to decades using statistical methods?
3) How does shrinking lake ice relate to lake level variability and lake water temperature?
4) Can we predict lake ice on synoptic time scales using a coupled Great Lakes Ice-circulation Model (GLIM)?

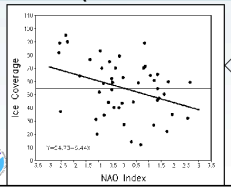
Which climate patterns (forcings) drive seasonal to decadal variability of lake ice & regional climate?





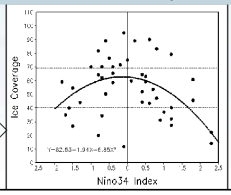
North Atlantic Oscillation (NAO) (Arctic Oscillation)

Pacific North America Pattern (El Nino/La Nina, ENSO)



Ice and NAO: Linear relationship

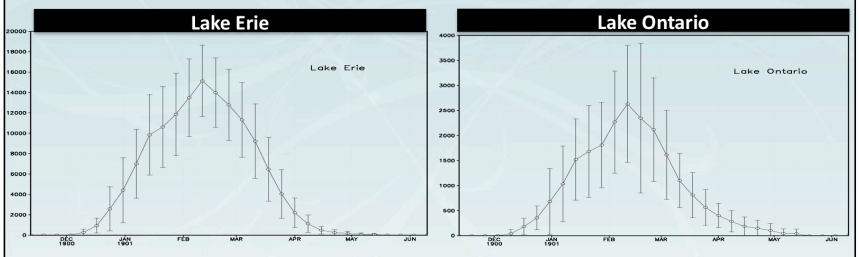
Ice and ENSO: Nonlinear relationship



The Great Lakes are not the action center – we are on the periphery of the action center.

Bai et al. (submitted to JGR)
Wang et al. EOS, 2010

What factors determine lake ice predictability from season to decades using statistical methods?



Climatology and standard deviations' characteristics:

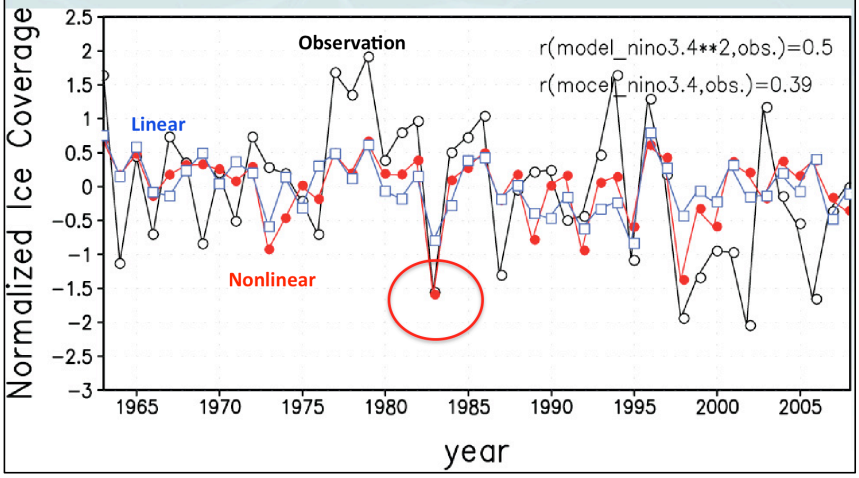
- Standard deviation ≥ mean! ➔ Large variability and poor skills for long-term predictions, and large uncertainty
- Standard deviation in shallow lakes (Erie) is smaller than in deep lakes (Ontario)➔Predictability in shallow lakes is higher than in deep lakes

These are two examples of graphs of Lakes Erie and Ontario with similar size surface areas but different depths.
For deep lakes standard deviation is equal to or greater than the mean, which means it is poor predictor of long-term ice.
Wang et al. submitted to J. Climate
Bai et al. submitted to JGR

What factors determine lake ice predictability from season to decades using statistical methods?

For non-linear regression model:

$Y=0.3-0.118xNino3.4-0.299xNino3.4^2 -0.208xNAO$



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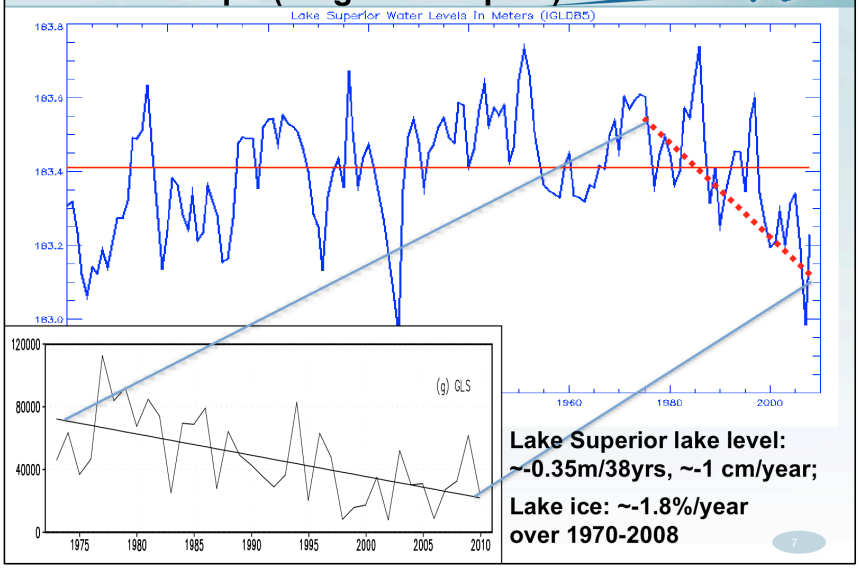
How does shrinking lake ice relate to lake level drop? (long-term impact)

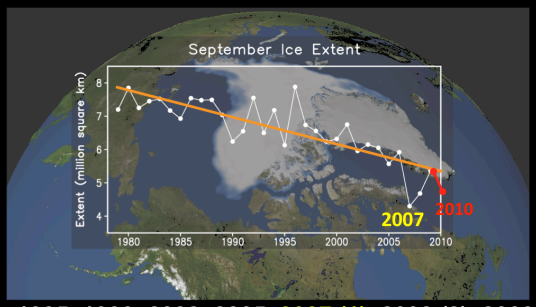


Lake Superior lake level: ~-0.35m/38yrs, ~-1 cm/year;

Lake ice: ~-1.8%/year over 1970-2008

Hypothesis:
Water level ~
+ *a* Ice (-Ta/Tw)
– *b* E(Ta/Tw, -Ice)
+ *c* P
+ *d* Runoff (land process~Ta/Tl, Veg., land-air energy budget)
Need a coupled model to test it! Wang et al. submitted to J. Climate

Arctic Summer Sea Ice Trend and Minima



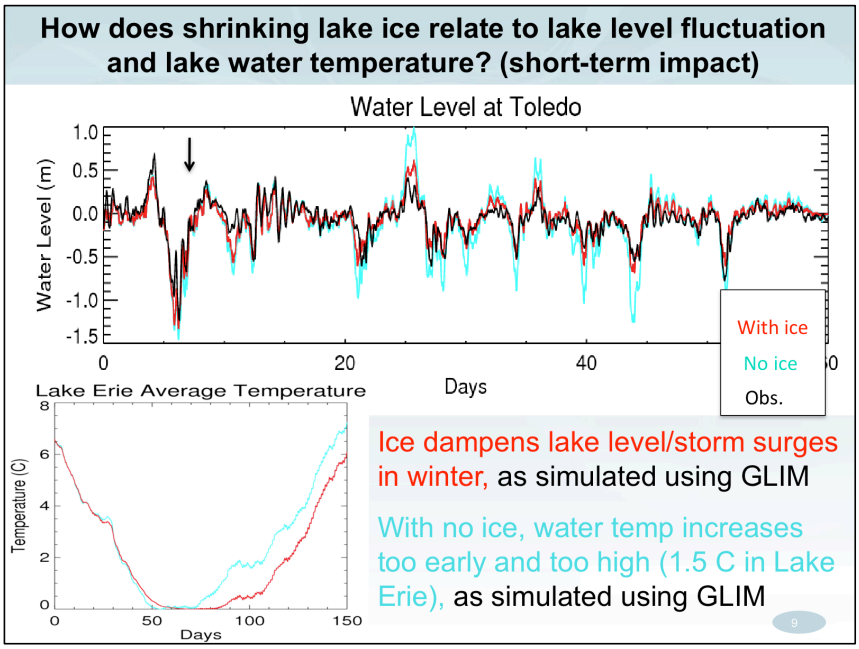
Minima in 1995, 1999, 2002, 2005, 2007 (1), 2008 (2), 2009 (4), 2010 (3):

The need for sea/lake ice forecasting, as stated in NOAA's Arctic Vision and Strategy (April 2010; Priority Goals):

1) Forecast Sea Ice;
2) Strengthen Fundamental Science to Understand and Detect Arctic Climate and Ecosystem Change; and
3) Enhance International and National Partnerships

Test in Lake Superior

Wang et al. GRL, 2009



Without lake ice in a model, the simulated water level using water only model is over-shot or overestimated; similarly, without sea ice in a model, the simulated lake water temperature using a water only model is over-heated.

Wang et al. 2010; JGLR

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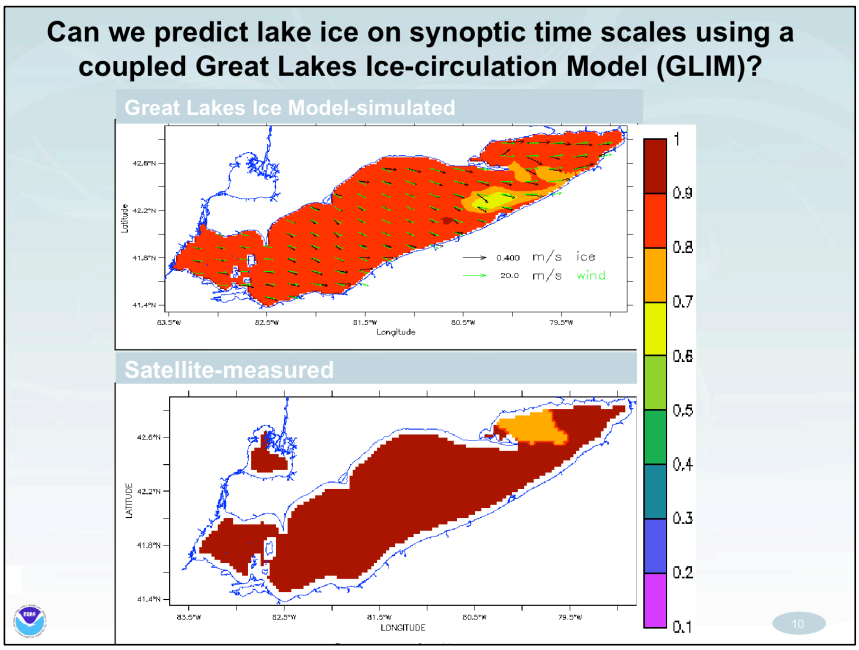

GLIM produces reasonable lake ice cover in comparison to satellite measurement.

Wang et al. 2010, JGLR

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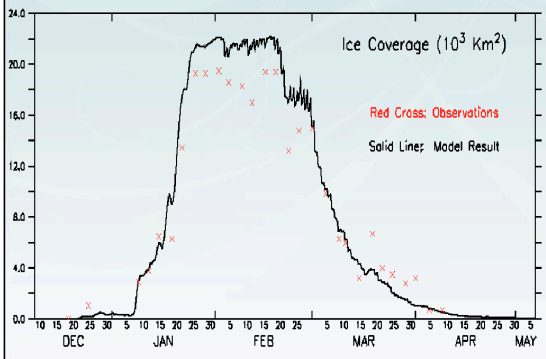
Can we predict lake ice on synoptic time scales using a coupled Great Lakes Ice-circulation Model (GLIM)?

GLIM-simulated ice area (cover) and thickness in 2004



GLIM was tested to be incorporated into GLERL's Great Lakes Coastal Forecasting System (GLCFS) for the 2009-2010 ice season

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Overall comparison between the simulated ice area and measured ice area by satellite is very good. (Wang et al. 2010, JGLR).
This is one of the NOAA's Climate Goals: Ice forecasting.
Potential users: Industries, U.S. Coast Guard, public/private, governments, academia.
Collaborators: National Weather Service, National Ice Center, University of Michigan.

Delivered Tools, Products and Services

- Ice climate analysis and statistical non-linear regression models (2007-present)
- Great Lakes Ice Atlas,1973-2010 ➔ Great Lakes Ice Mapping System (GL- IMS) (2007-present)

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http://www.glerl.noaa.gov/data/ice/atlas/

Delivered Tools, Products and Services

- Great Lakes Ice-circulation Model (GLIM) delivered to GLCFS, (2007-present)
- Unstructured-grid, entire Great Lakes watershed-scale GLIM for climate studies: Hindcast and downscaling simulations, projection of climate scenarios into GL watershed scale

  (to be coupled to GL WRF (regional climate model), ecosystems model, and other subsystem models to develop capability for climate studies in line with National Climate Service)

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http://www.glerl.noaa.gov/data/ice/atlas/

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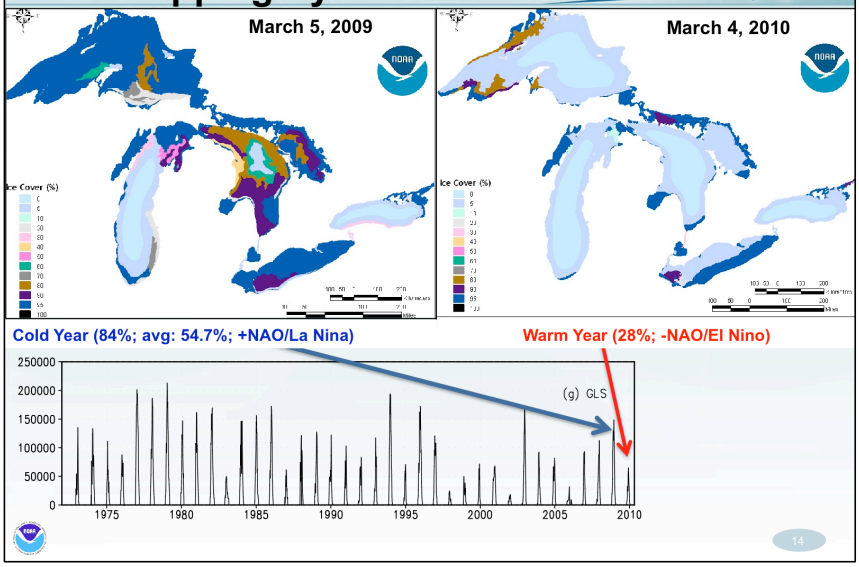
Great Lakes Ice Atlas,1973-2010 ➔Ice Mapping System



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The update of the Great Lakes Ice Atlases are necessary and advance our understanding of climate change (Wang et al. 2010, submitted to J. Climate).

This is one of the NOAA's Climate Goals: Ice forecast.
Potential users: Industries, U.S. Coast Guard, public/private, governments, academia.

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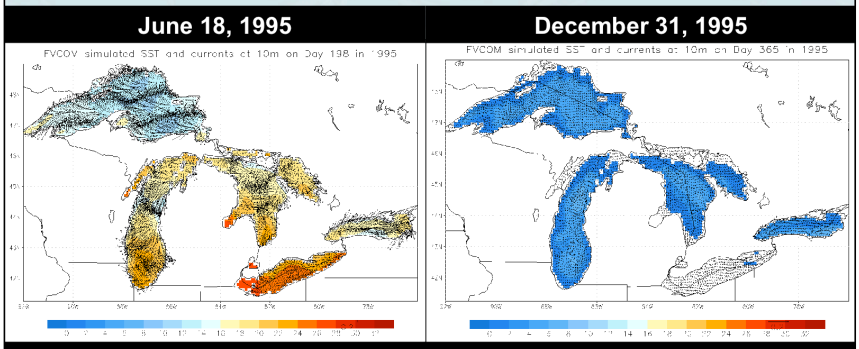
Unstructured-grid, entire Great Lakes Watershed-scale GLIM



Simulated surface current and SST

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High-resolution, coupled GLIM on a Great Lakes watershed scale is essential for regional climate simulation, downscaling, and projection.

Future Directions

- Continue interdisciplinary research associated with lake ice and climate
- Continue to improve Great Lakes Ice-circulation Model (GLIM) for Great Lakes Coastal Forecasting System
- Upgrade Great Lakes Ice Atlas to web-based, user-friendly Great Lakes Ice Mapping System
- Develop unstructured-grid *integrated* ice-circulation-ecosystem modeling capability for climate studies
- Couple to atmosphere and hydrology to develop regional *Great Lakes Earth System Model*

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Further information:

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http://www.glerl.noaa.gov/about/pers/profiles/wang.html